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CARLSTROM, OSTRIKER, AND PAGE RECEIVE $500,000 GRUBER COSMOLOGY PRIZE FOR THEORETICAL AND EXPERIMENTAL EXPLORATIONS OF THE UNIVERSE

John Carlstrom

Jeremiah Ostriker

Lyman Page

June 9, 2015, New Haven, CT – The 2015 Gruber Foundation Cosmology Prize recognizes John E. Carlstrom, Jeremiah P. Ostriker, and Lyman A. Page, Jr., for their individual and collective contributions to the study of the universe on the largest scales.

The 2015 prize is divided into two parts: half to a distinguished theorist, and the other half to two exceptional experimentalists. The theorist is Ostriker, who is being honored for his groundbreaking body of work over a five-decade career, while Carlstrom and Page have each overseen ground-based experiments providing a wealth of information about the origins and evolution of the universe. Together the theoretical and experimental work of these three scientists has contributed to, clarified, and advanced today's standard cosmological model.

Ostriker will receive half of the $500,000 award, while Carlstrom and Page will divide the other half. Each will also receive a gold medal at the XXIX General Assembly of the International Astronomical Union in Honolulu, Hawaii, on August 3.

The current scientific interpretation of the universe began to crystallize in the mid-1960s with the discovery of relic radiation from the infancy of the universe. This radiation, called the cosmic microwave background (CMB), finally allowed scientists to test the longstanding and sometimes contradictory predictions of competing cosmologies. The winner: the Big Bang model— a universe that arose out of an inconceivably dense state of matter and energy, and has been expanding and cooling ever since, eventually coalescing into today's familiar skyscape of planets, stars, and galaxies.

Over the past five decades, experiments and theories have rapidly (at least on the scale of most scientific progress) led to a scientific consensus about the Big Bang universe: what's in it and how it

came to look the way it does today. Our universe appears to consist of part dark energy, part dark matter, and part regular matter. In addition, the distribution of all that energy and matter seems to have been determined by a primordial hyper-expansion of space called inflation.

The work of this year's Gruber recipients has made extraordinary contributions to the understanding and refinement of that model.

Jeremiah P. Ostriker, now an emeritus professor at Princeton University and currently teaching at Columbia University, belonged to the first generation of theorists who examined how such a universe might operate. He has made significant contributions to the studies of galaxy formation, the interstellar medium, and the intergalactic medium. But he has also achieved renown for helping to overturn two basic assumptions about the very nature of the universe.

In the early 1970s he noticed that a spiral galaxy like our own Milky Way could not rotate stably according to Newton's laws if it only contained the matter we can see in the stars. It shouldn't be able to complete even one rotation without wobbling and breaking apart into a binary galaxy or a bar, at least if you take the galaxy at face value—that is, if you assume that the visible stars and gas are the only matter in the galaxy. Ostriker and his Princeton University colleague P. James E. Peebles (the recipient of a 2000 Gruber Cosmology Prize) challenged that assumption. In 1973 they reported that computer simulations indicated that if such a galaxy were immersed in a sufficiently dense halo of some sort of invisible mass, it could in fact remain gravitationally stable. And they soon showed that there was a great deal of other evidence for extra matter outside of the visible galaxy.

Today we call that mysterious substance dark matter. Although cosmologists don't know what dark matter is, they do know what it does. It serves as the glue that not only stabilizes galaxies and clusters of galaxies but gives the universe its web-like structure on the largest scales: vast filaments of super-clusters of galaxies spanning hundreds of millions of light-years, separated by even vaster voids.

In 1995, Ostriker and another Princeton colleague, Paul J. Steinhardt, argued that the total amount of matter alone in the universe, dark or otherwise, is at odds with some key theoretical implications of Big Bang cosmology. Again, Ostriker and Steinhardt invoked a mysterious missing component that would be permeating the universe. Some other theorists were making the same argument—and in fact evidence for that component was discovered within three years by two competing teams of observers (led by Saul Perlmutter and Brian Schmidt, who along with their team members received the 2007 Gruber Prize in Cosmology). In retrospect, though, what distinguishes Ostriker and Steinhardt's paper is the suggestion that this component, today known as dark energy, should contribute about 70 percent to the total mass and energy of the universe—a figure validated by a number of later observations, including those made by the instruments overseen by John E. Carlstrom and Lyman Alexander Page, Jr.

While both Page and Carlstrom have worked extensively in the study of the CMB, they currently lead two projects in particular. Carlstrom, who has been at the University of Chicago since 1995, is the principal investigator on the South Pole Telescope, which was constructed at the U. S. science station at the Pole in late 2006 and early 2007. Page, who has been at Princeton since 1990, serves in the same capacity for the Atacama Cosmology Telescope, which was constructed on Cerro Toco in the mountainous Atacama Desert in Chile in 2007.

Those instruments, both still active, probe the CMB, the relic radiation discovered in the 1960s, inaugurating the modern era of cosmology. When the universe was 380,000 years old it had cooled enough for hydrogen atoms and photons to decouple and go their separate ways. That "flashbulb" moment has survived as a sort of snapshot—a "baby picture" of the universe—though over the past

13.7 billion years the expansion of space has stretched the light from the image all the way into the microwave end of the electromagnetic spectrum. Look closely enough and finely enough at the CMB, though, and you should be able to see extraordinarily subtle shadings in temperature: the DNA for the galaxies, clusters of galaxies, and super-clusters of galaxies that populate the universe as we know it.

Among the many contributions to cosmology that those instruments have made are: the discovery of hundreds of clusters of galaxies going back to when the universe was about one-third its present age, providing a history of the growth of the large-scale structure of the universe; independent verification that the universe consists of approximately 25 percent dark matter, 70 percent dark energy, and 5 percent atoms; and strong evidence that the structure in the CMB is a remnant of quantum fluctuations. This latter data provides support for inflation, a theory which in turn suggests that the universe itself is one big quantum fluctuation.

What is dark matter? What is dark energy? How to explain a quantum universe? In honoring Carlstrom, Ostriker, and Page, the 2015 Gruber Cosmology Prize recognizes science doing what science does best: answering fundamental questions while opening new frontiers for observers and theorists alike and raising new fundamental questions to puzzle us.

Additional Information

In addition to the cash award, each recipient will receive a gold laureate pin and a citation that reads:

The Gruber Foundation proudly presents the 2015 Cosmology Prize to Jeremiah P. Ostriker for wide-ranging theoretical work over 50 years, which has clarified our understanding of galactic structure and evolution, dark matter, the intergalactic medium and high energy astrophysics; and to John Carlstrom and Lyman Page for their leadership in ground-based observational CMB cosmology, including instrumentation: from TOCO and DASI to the South Pole Telescope and the Atacama Cosmology Telescope.

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Laureates of the Gruber Cosmology Prize:

- **2014: Jaan Einasto, Kenneth Freeman, Brent Tully and Sidney van den Bergh** for their pioneering contributions to the understanding of the structure and composition of the nearby Universe.
- **2013: Viatcheslav Mukhanov** and **Alexei Starobinsky** for their profound contribution to inflationary cosmology and the theory of inflationary perturbations of the metric. These developments changed our views on the origin of our universe and on the mechanism of formation of its structure.
- **2012: Charles Bennett and the WMAP Team** for their exquisite measurements of anisotropies in the relic radiation from the Big Bang---the Cosmic Microwave Background.
- **2011: Marc Davis, George Efstathiou, Carlos Frenk** and **Simon White** for their pioneering use of numerical simulations to model and interpret the large-scale distribution of matter in the Universe
- **2010: Charles Steidel** for his groundbreaking studies of the distant Universe
- **2009: Wendy Freedman, Robert Kennicutt** and **Jeremy Mould** for the definitive measurement of the rate of expansion of the universe, Hubble's Constant

- **2008: J. Richard Bond** for his pioneering contributions to our understanding of the development of structures in the universe
- **2007: Saul Perlmutter** and **Brian Schmidt** and their teams: the **Supernova Cosmology Project** and the **High-z Supernova Search Team,** for independently discovering that the expansion of the universe is accelerating
- **2006: John Mather** and the **Cosmic Background Explorer (COBE) Team** for studies confirming that our universe was born in a hot Big Bang
- **2005: James E. Gunn** for leading the design of a silicon-based camera for the Hubble Space Telescope and developing the original concept for the Sloan Digital Sky Survey
- **2004: Alan Guth** and **Andrei Linde** for their roles in developing and refining the theory of cosmic inflation
- **2003: Rashid Alievich Sunyaev** for his pioneering work on the nature of the cosmic microwave background and its interaction with intervening matter
- **2002: Vera Rubin** for discovering that much of the universe is unseen black matter, through her studies of the rotation of spiral galaxies
- **2001: Martin Rees** for his extraordinary intuition in unraveling the complexities of the universe
- **2000: Allan R. Sandage** and **Phillip J. E. (Jim) Peebles**: Sandage for pursuing the true values of the Hubble constant, the deceleration parameter and the age of the universe; Peebles for advancing our understanding of how energy and matter formed the rich patterns of galaxies observed today

The Prize recipients are chosen by the Cosmology Selection Advisory Board. Its members are:

Andrew Fabian, University of Cambridge; **Wendy Freedman,** University of Chicago (Chair); **Helge Kraghe,** Niels Bohr Institute; **Frans Pretorius,** Princeton University; **Sadanori Okamura,** Hosei University; **Subir Sarkar**, University of Oxford; and **Rashid Sunyaev**, Max Planck Institute for Astrophysics. **Owen Gingerich** of the Harvard-Smithsonian Center for Astrophysics and **Martin Rees** of the University of Cambridge also serve as special Cosmology advisors to the Foundation.

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By agreement made in the spring of 2011 The Gruber Foundation has now been established at Yale University.

The Gruber International Prize Program honors individuals in the fields of Cosmology, Genetics and Neuroscience, whose groundbreaking work provides new models that inspire and enable fundamental shifts in knowledge and culture. The Selection Advisory Boards choose individuals whose contributions in their respective fields advance our knowledge and potentially have a profound impact on our lives.

The Cosmology Prize honors a leading cosmologist, astronomer, astrophysicist or scientific philosopher for theoretical, analytical, conceptual or observational discoveries leading to fundamental advances in our understanding of the universe.

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Affiliation with International Astronomical Union

In 2000, The Foundation and the International Astronomical Union (IAU) announced an agreement by which the IAU provides its expertise and contacts with professional astronomers worldwide for the nomination and selection of Cosmology Prize winners. Under the agreement, The Gruber Foundation also funds a fellowship program for young astronomers, with the aim of promoting the continued recruitment of new talent into the field.

The International Astronomical Union, founded in 1919, is an organization of professional astronomers. It serves today a membership of more than 9,000 individual astronomers from 85 countries, worldwide. Information about the activities of the IAU is available from www.iau.org .

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For more information on the Gruber Prizes, visit www.gruber.yale.edu , e-mail info@gruber.yale.edu or contact A. Sarah Hreha at +1 (203) 432-6231. By mail: The Gruber Foundation, Yale University, Office of Development, PO Box 2038, New Haven, CT 06521.

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